Study on self-insulation wall system of autoclaved aerated concrete with high energy saving

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Abstract. In this paper, a high energy-saving self-insulation wall system of autoclaved aerated concrete (AAC) is established by analysis its construction and the performances of the wall system are also discussed. The results show that the wall system based on combining different density AAC slabs can achieve good thermal performance and the value of the heat transfer coefficient is lower than 0.35W/(m^2·K) with the thickness of the wall not exceeding 300mm (without the thickness of plastering layer). It is indicating that the high energy-saving effect can be obtained through a single material, moreover, the wall function integration of enclosure and insulation can be realized. The self-insulation wall system of AAC effectively solves the problems that the traditional exterior insulation system in China is prone to the risk of falling off, hollowing, and cracking.

Keywords: High energy-saving, wall system, self-insulation, autoclaved aerated concrete

1 Introduction

With the rapid development of steel structure buildings, China has developed a series of supporting walls [1-2]. For the steel structure housing, there are four external wall enclosure systems recommended, including assembled light panel external wall system [3-4], assembled skeleton composite panel external wall system, assembled prefabricated external wall system, and assembled composite external wall system[5-7]. For the assembled light panel exterior wall system mentioned above, the AAC exterior wall system is a widely used. In order to achieve higher energy-saving requirements, it is usually necessary to combine with the external insulation board on site or in the factory to form an external insulation system, so as to meet the requirements of high energy saving [8-11]. However, with the continuous improvement of energy saving requirements, the thickness of external thermal insulation layer is increasing, which brings hidden danger of falling off, and also puts forward high requirements for the strength of wall substrate and construction quality. The self-insulation system refers to the fact that the wall material itself can meet the prescribed building energy-saving requirements without the need to make an insulation layer on the surface of the inner and outer walls of the building. Therefore, the development of a wall system integrating wall

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enclosure and self-insulation is an effective way to further improve the safety, healthy development and energy saving level of China 's walls [12].

In this paper, according to the newly revised 80% energy-saving requirement of Beijing, the self-assembled wall structure is designed based on the thermal performance of AAC slabs with different dry density (Figure 1), the structure of self-insulation wall composed of AAC single wall material is put forward, which provides technical support for the new energy-saving standard.

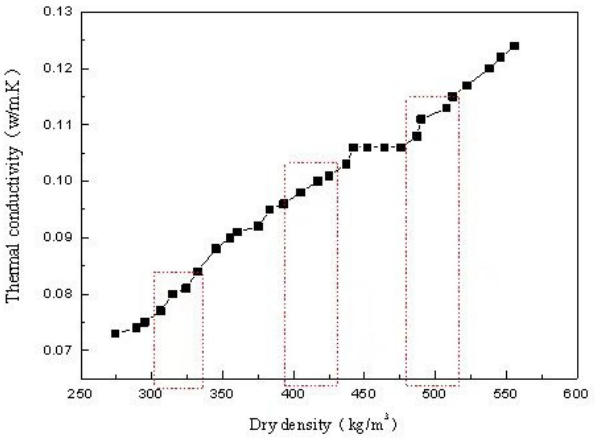

Fig. 1. Relationship curve between thermal conductivity and dry density

2 Design and construction of AAC high energy-saving self-insulation wall system

2.1 Construction of wall system

Table 1. Construction scheme of wall system

Construction scheme 1				
Items	Inner leaf wall	Middle layer	Outer leaf wall	Protective layer
Material type	03 AAC slab	Air layer	05 AAC slab	Mortar
Material thickness (mm)	150	0	150	20
Thermal conductivity λ[W/(m·K)]	0.08	0.026	0.12	0.93
Heat transfer coefficient (measured values)	0.33			

U[W/(m2·K)]				
Construction scheme 2				
Items	Inner leaf wall	Middle layer	Outer leaf wall	Protective layer
Material type	04 AAC slab	Air layer	05 AAC slab	Mortar
Material thickness (mm)	125	25	150	20
Thermal conductivity λ[W/(m·K)]	0.10	0.026	0.12	0.93
Heat transfer coefficient (measured values) U[W/(m2·K)]	0.32			

Based on the measured results of thermal conductivity of AAC products with different dry density, the structural design of self-insulation composite wall are carried out, and two construction schemes are worked out. The construction 1 is (03 + 05) AAC self-insulation composite wall, and the measured heat transfer coefficient is 0.33 W/(m^2·K), the construction 2 is (04 + 05) AAC self-insulation composite wall with a air cavity of 25 mm. The measured heat transfer coefficient is 0.32 W/(m^2·K). As shown in Table 1, the measured heat transfer data of the two systems are lower than 0.35 W/(m^2· K) which meet the heat transfer coefficient requirement of 80 % energy-saving in Beijing.

2.2 Interface condensation calculation and analysis of AAC self-insulation wall

Table 2. Interface condensation calculation model of construction scheme 1

Interface order	Interface description of wall layers
Inner surface 1	interior decorative layer surface of the wall
Interface 2	Between interior decorative layer and 03 AAC slab
Interface 3	between 03 AAC and bonding mortar
Interface 4	between bonding mortar and 05 AAC slab
Interface 5	between 05 AAC slab and protective mortar
Outer surface 6	Outer surface of protective mortar

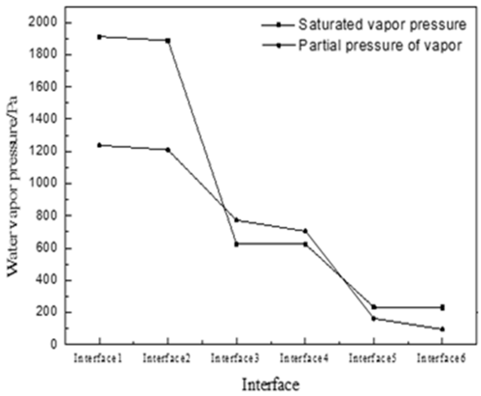

Fig. 2. Condensation calculation of (03+05) AAC wall system (Construction scheme 1).

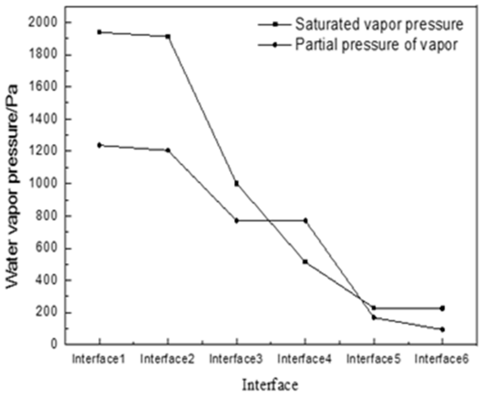

Fig. 3. Condensation calculation of (04+05) AAC wall system (Construction scheme 2).

Table 3. Interface condensation calculation model of construction scheme 2

Interface order	Interface description of wall layers
Inner surface 1	interior decorative layer surface of the wall
Interface 2	Between interior decorative layer and 04 AAC slab
Interface 3	between 04 AAC and air layer
Interface 4	between air layer and 05 AAC slab
Interface 5	between 05 AAC slab and protective mortar
Outer surface 6	Outer surface of protective mortar

In this paper, the condensation calculation and analysis of the main interfaces of the structural wall layers according to the self-insulation construction scheme 1and construction scheme 2 of the AAC self-insulating composite wall system are performed (as shown in Table 2 and Table 3).The 03 or 04 class AAC slabs with lower dry density is placed on the inner side of the wall as the inner leaf wall, which has the tendency of condensation at the interface of the double-layer wall. As shown in Figure 2 and Figure 3, the interface 3 and interface 4 have the possibility of condensation. This phenomenon is mainly due to the fact that AAC is porous concrete, and its water vapor transmission rate is large. As the internal temperature of the wall decreases from inside to outside, condensation may occur.

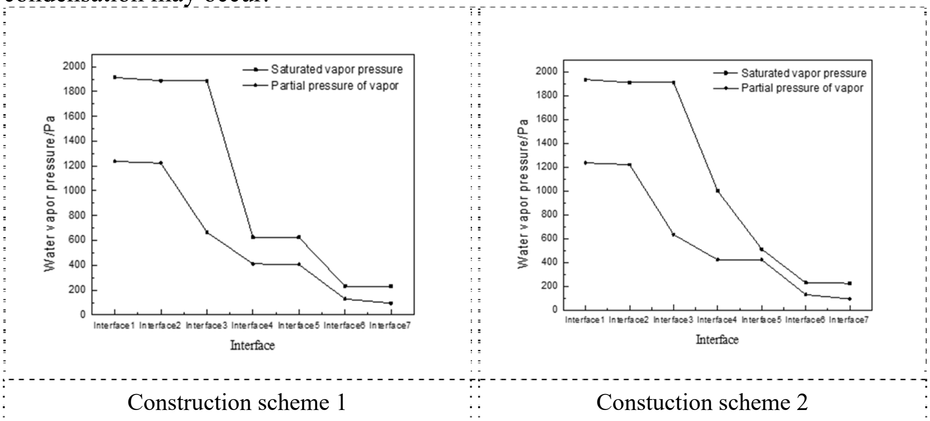

Fig. 4. Condensation calculation after steam insulation treatment of main section

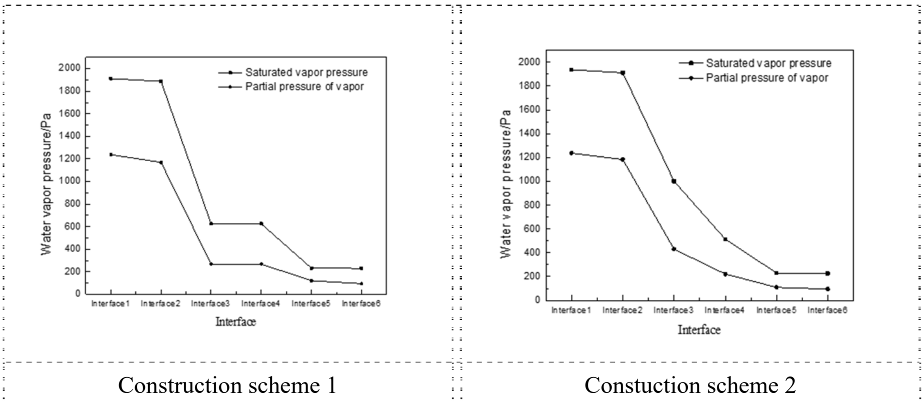

Fig. 5. Condensation calculation after setting vent valve of main section

As it can be seen from Figure 4, when the indoor side of the wall is treated with steam insulation, condensation inside the self-insulation wall can be avoided. Or the gas pipe from the inside of the wall to the outside of the wall can also solve the condensation problem inside the wall, as shown in Figure 5. However, no matter which way, it should be emphasized that the facing layer supporting the AAC self-insulation system should have good air permeability to ensure the "breathing" effect of the wall.

In this section, by interface treatment or setting vent valve as moisture-discharging structure, the problem of condensation at middle interface of double-layer wall caused by inner wall with low density AAC is solved effectively.

3 Measurement and performance of AAC self-insulation wall system

Fig. 6. Construction of the self-insulation wall system with two layers of different dry density of AAC

Fig. 7. Performance evaluation of the self-insulation wall system with two layers of different dry density of AAC

At present, there is no standard for the system performance evaluation of the wall system (as shown in Figure 6), because the wall is a steel structure envelope wall system, and it has certain similarity with the building glass curtain wall. In this paper, the wall performance test method of building glass curtain wall is introduced into the performance evaluation of enclosure wall, the performance of the wall system is investigated in the aspect of wind pressure resistance, and the integrity and good functionality of the wall system are evaluated by the performance of air-tightness and water-tightness of the wall system after the above-mentioned tests. The evaluation of wall system performance is shown in Table 4 and Figure 7.

Table 4. Performance evaluation of AAC self-insulation wall system

No.	Test items	According standard	Measured value	Evaluation result
1	Static pressure air tightness performance	Curtain wall for building (GB/T 21086)	q_A/ [$m^3/(m^2 \cdot h)$] 0.240 (positive pressure) 0.200 (negative pressure)	Air tightness level 4
2	Thermal cycle performance	The heat and cold cycles were repeated three times, and the high temperature (50°C) and low temperature (-20°C)lasted for 8 hours each.	—	There is no visible failure area, no detachment and no cracks in the wall specimens. No sealant or wall installation failure, no permanent deformation.
3	Anti-condensation test	Low temperatures of -11 °C and -20 °C were maintained for 8 hours.	—	No condensation
4	Static pressure water tightness performance after thermal cycling	Curtain wall for building (GB/T 21086)	The maximum pressure of the wall is 1000Pa, and the maximum pressure of the open part is 500PA. The wall has no leakage and keeps good function and integrity	Water tightness level 3
5	Dynamic pressure water tightness performance after wind pressure resistance	AAMA 501.1-05	The wall has no leakage and keeps good function and integrity.	0.72kPa

4 Conclusions

AAC self-insulation wall system is one of the ways to realize energy-saving, safety and the same life as building based on the combination of different bulk density AAC slabs.

The results show that the wall system based on combining different density AAC slabs can achieve good thermal performance and the value of the heat transfer coefficient is lower than $0.35W/(m^2 \cdot K)$ with the thickness of the wall not exceeding 300mm (without plastering layer). It is indicating that the high energy-saving effect can be obtained through a single material. Moreover, the wall function integration of enclosure and insulation can be realized. It effectively solves the problems that the traditional exterior insulation system in China is prone to the risk of falling off, hollowing, and cracking.

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